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(71) Applicant
Sarasota Automation Limited (United Kingdom),
Kings Worthy, Winchester, Hampshire SO23 7QA

(72) Inventor
Brian Charles Jefferis

(74) Agent and/or Address for Service
Lloyd Wise Tregear & Co,
Norman House, 105–109 Strand, London WC2R 0AE

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(58) Field of search
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G1N
H3T

(54) Inductive loop vehicle-sensing

(57) In an inductive loop detector for sensing the presence of vehicles, in which a road loop is coupled as part of the inductance in the tank circuit of an oscillator, the operating frequency of the oscillator is tuned by application of a parallel digital number, (e.g. from a microprocessor) to a tuning control circuit which changes the inductance in the tank circuit in response to change in the digital number. In one arrangement, the digital number is applied to a controllable network, such as a digital-to-analog converter, having a voltage output or voltage characteristic that varies according to the digital input, and the varying voltage or voltage characteristic is employed to vary the tuning inductance coupled to the oscillator. In another arrangement, the road loop is coupled to the oscillator tank circuit by a multi-tap transformer the transformer ratio of which varies in accordance with the applied digital number.

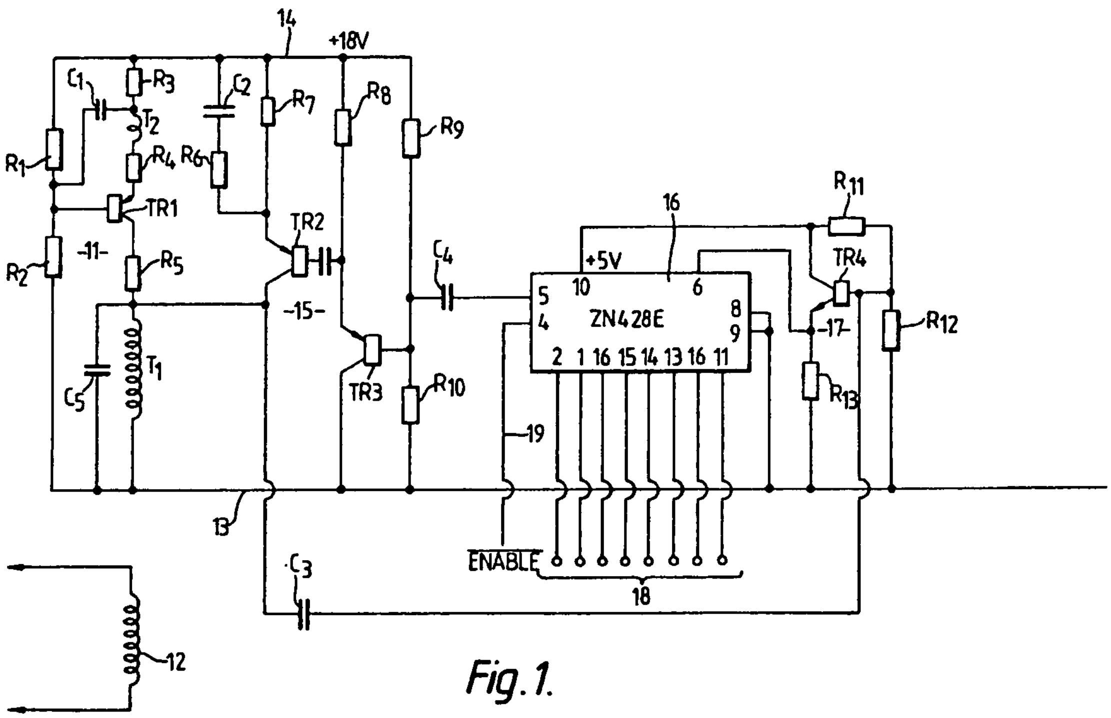

Fig.1.

The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.

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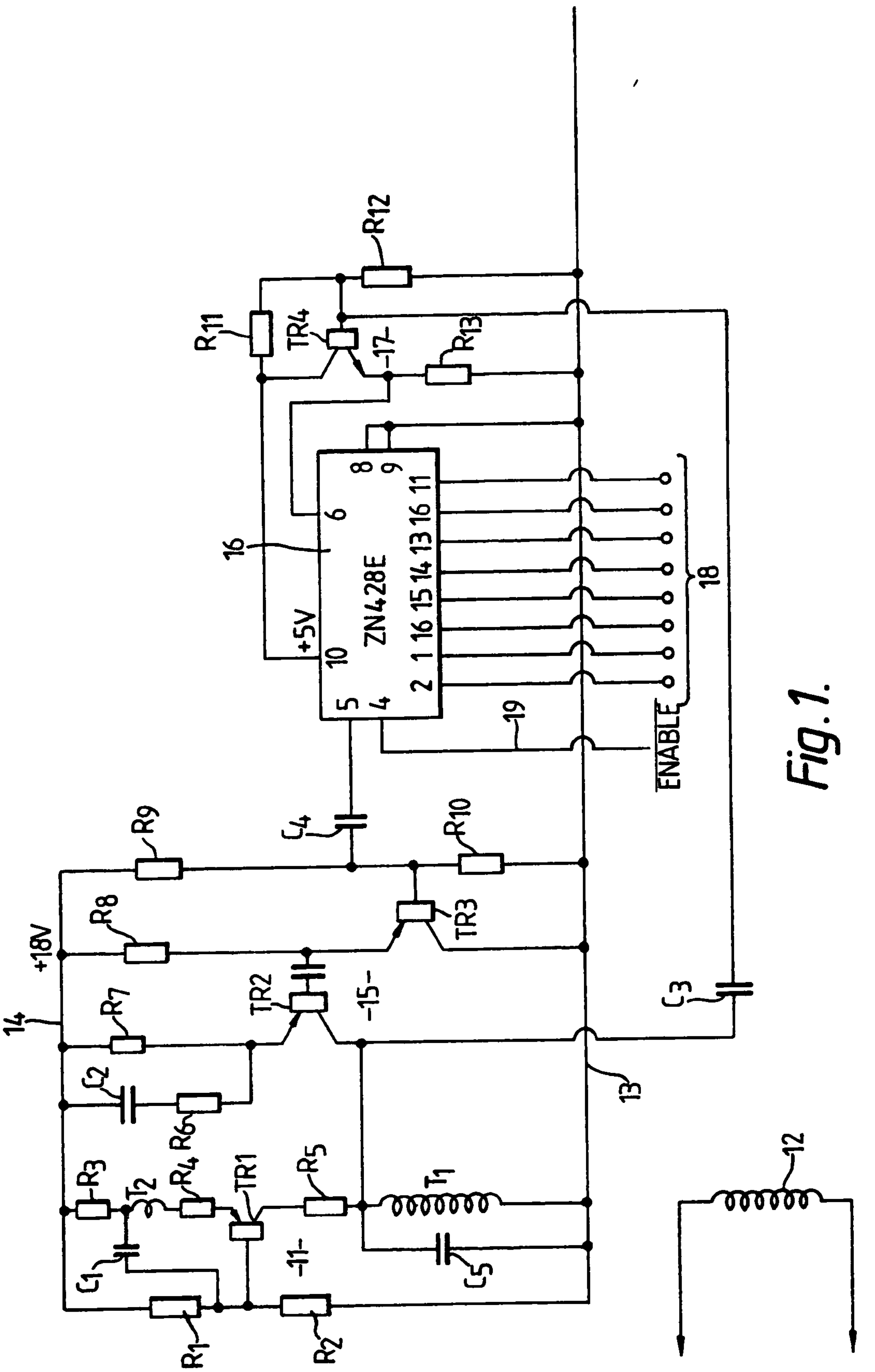

Fig. 1.

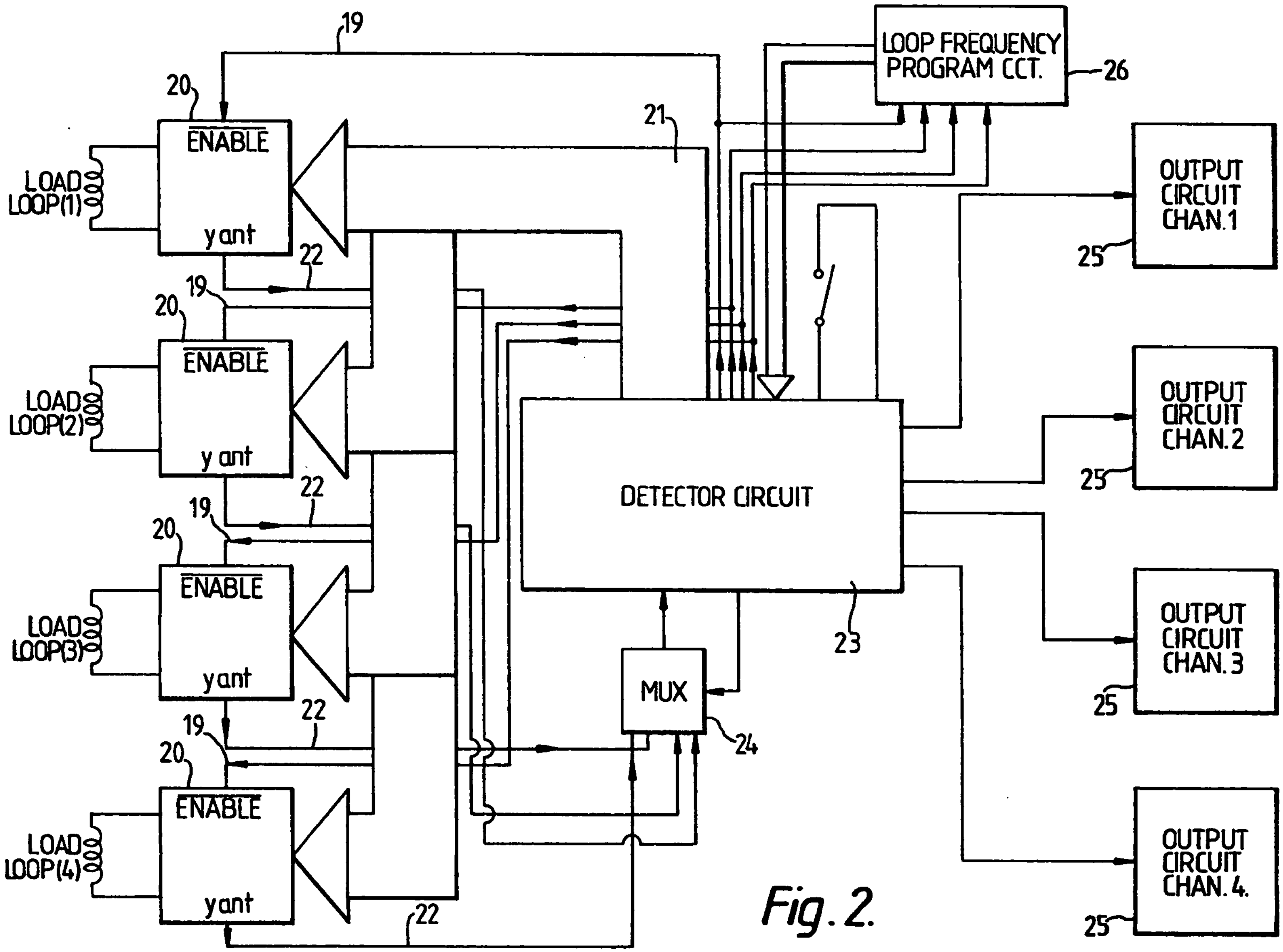
19
20
ENABLE
LOAD LOOP(1)
y ant
22
19
20
ENABLE
LOAD LOOP(2)
y ant
22
19
20
ENABLE
LOAD LOOP(3)
y ant
22
19
20
ENABLE
LOAD LOOP(4)
y ant
22
21
LOOP FREQUENCY PROGRAM CCT.
26
DETECTOR CIRCUIT
23
MUX
24
OUTPUT CIRCUIT CHAN.1
25
OUTPUT CIRCUIT CHAN.2
25
OUTPUT CIRCUIT CHAN.3
25
OUTPUT CIRCUIT CHAN.4.
25

Fig. 2.

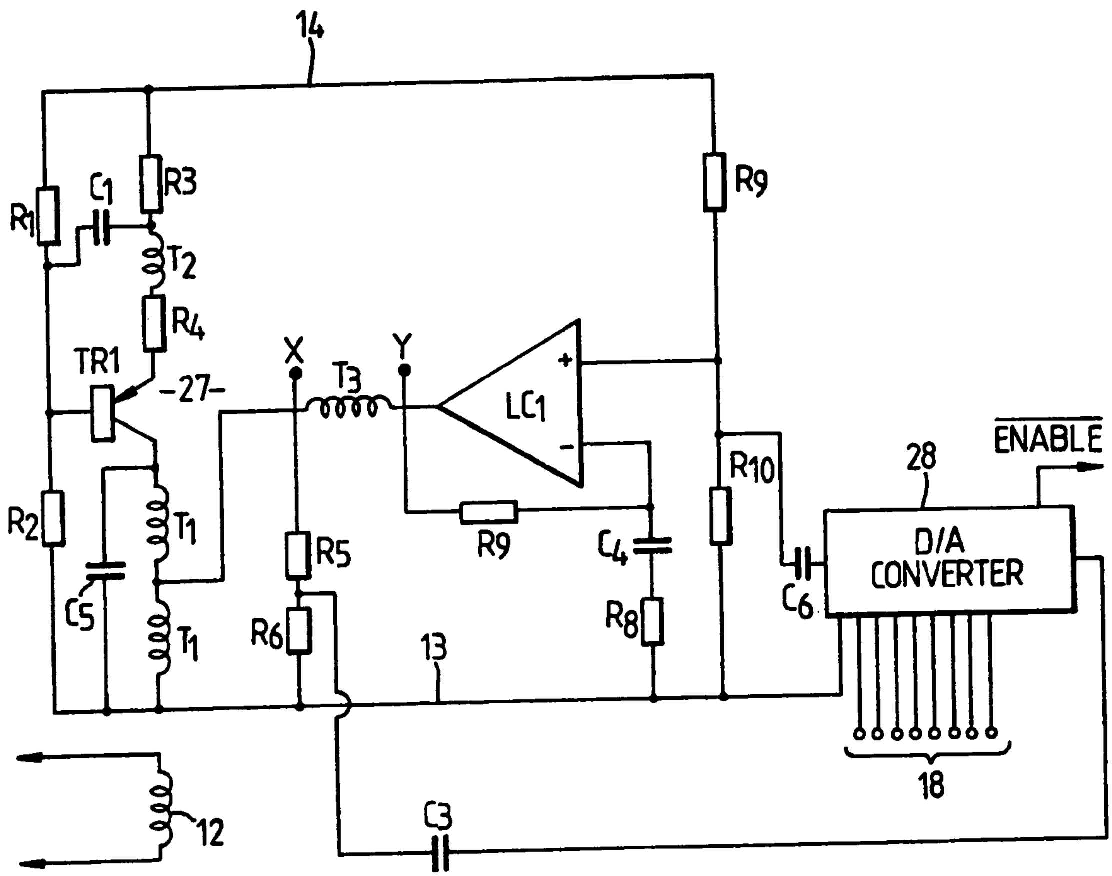
14
R1
C1
R3
T2
R4
TR1
-27-
X
T3
Y
LC1
+
-
R9
R2
T1
C5
T1
R5
R6
R9
C4
R8
R10
C6
28
ENABLE
D/A CONVERTER
13
18
12
C3

Fig.3.

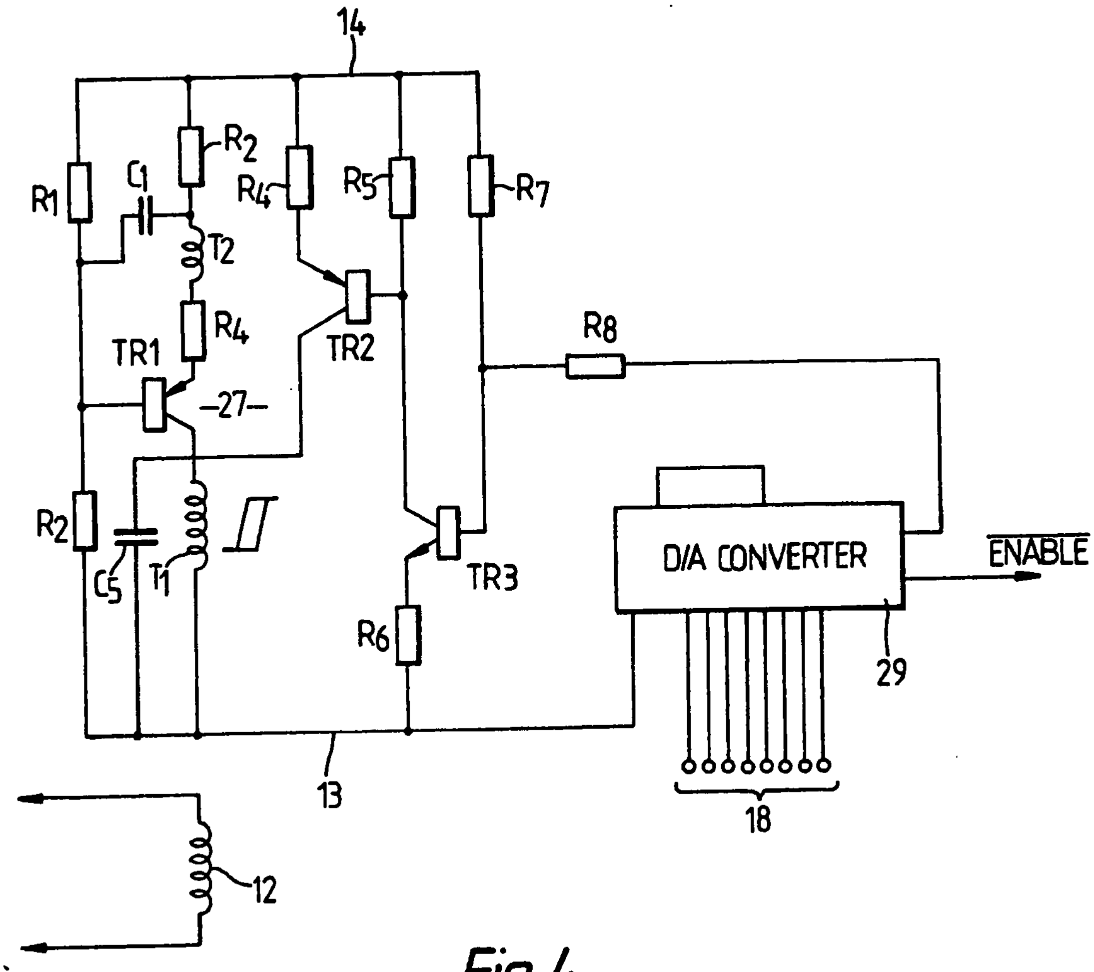
14
R1
C1
R2
T2
R4
R4
R5
R7
TR1
TR2
R8
-27-
R2
C5
T1
TR3
D/A CONVERTER
ENABLE
R6
29
13
18
12

Fig.4.

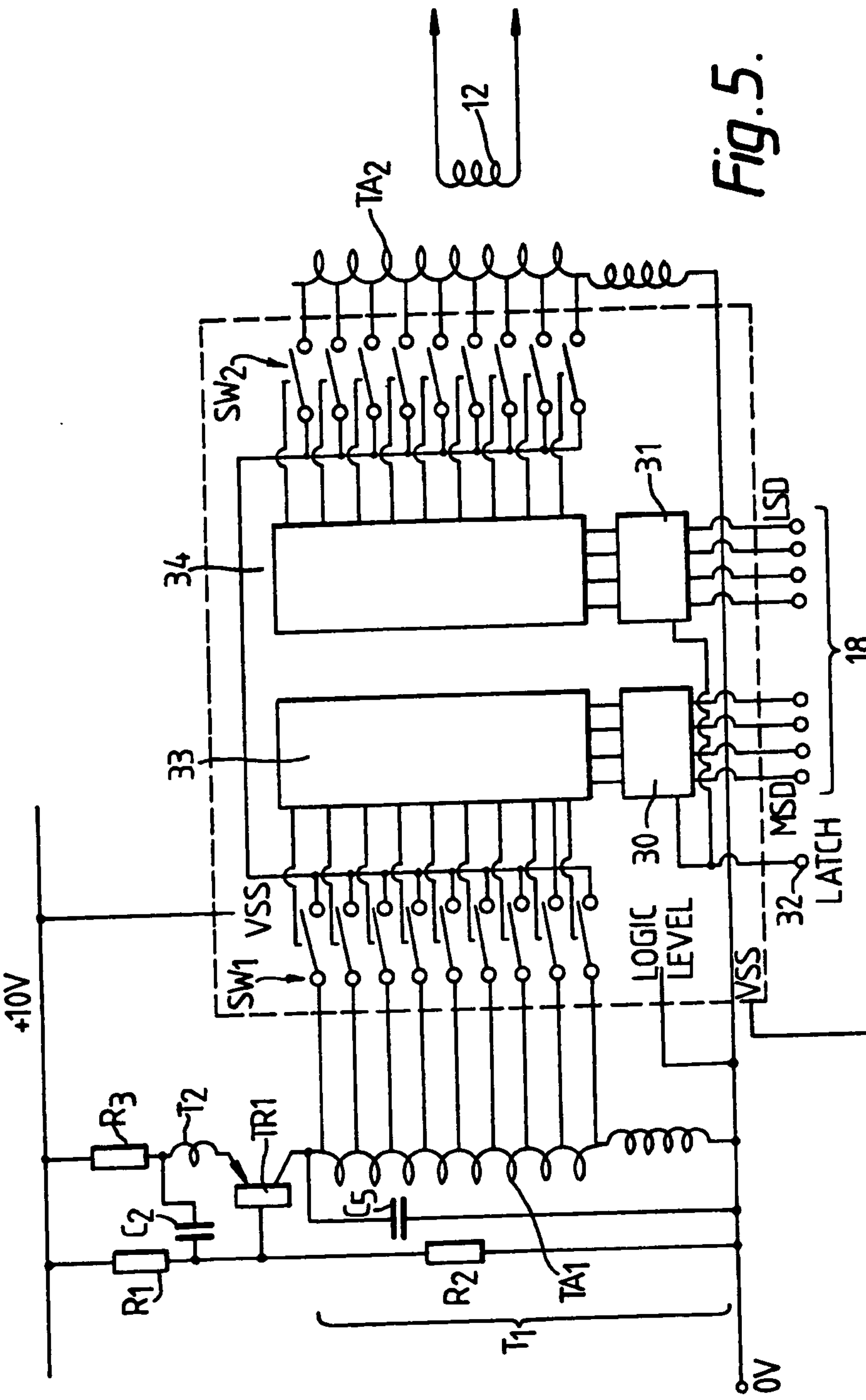
12
TA2
SW2
31
34
LSD
18
33
MSD
30
LATCH
32
VSS
SW1
LOGIC
LEVEL
VSS
-10V
+10V
R3
T2
TR1
C2
C5
R1
R2
TA1
T1
0V

Fig.5.

SPECIFICATION

Improvements in loop oscillators for use in inductive loop vehicle-sensing circuitry

This invention relates to inductive loop detectors, such as are employed in automatic vehicle-responsive road traffic light signal installations.

It is common practice in vehicle detection to employ an inductive sensor loop as the frequency-determining element of a tuned circuit in a loop oscillator. An inductance change in the loop due to the arrival of a vehicle can be sensed as a consequence of the change in oscillator frequency. However, whereas changes in the frequency of oscillation are used to derive signals denoting the arrival and departure of vehicles, there are at the same time statutory regulations concerning the frequency band allocations for such apparatus and also it is highly desirable that one detector shall not stray into the frequency range within the allocated band that has been allotted to another detector, in order to avoid cross-talk. There is thus a need not only to provide loop oscillators the installed operating frequency range of which is within certain defined limits but also to cope with the problem that can arise if large loop inductance changes occur in service due to vehicle movement or environmental changes. It is thus an object of the present invention to achieve a loop oscillator that fulfills these needs without undue expense or complexity of circuitry.

According to the present invention, there is provided inductive loop detector circuitry for sensing vehicles, including a loop oscillator having an LC resonant circuit in which the loop provides part of the inductance, and wherein the overall inductance is variable to vary the tuning of the oscillator operating frequency by means of a tuning control circuit responsive to application of a variable digital number as control input.

In one arrangement, a digital-to-analogue converter receives the digital number which determines its output voltage, or its input-output voltage transfer characteristic, and this output voltage or voltage transfer characteristic, representative of the input digital number, is employed to vary the tuning inductance and thereby regulate the operating frequency of the oscillator. There are a variety of ways of obtaining this result. The converter can, for instance, be connected as a variable attenuator in a feedback loop of a current amplifier that delivers an inductive current output coupled into the oscillator tank circuit. Or the variable tuning can be accomplished by employing the converter output to control the phantom inductance of a variable reactance loop transformer.

In another arrangement, one or more multi-tap transformers are employed to couple the loop to the oscillator tank circuit thereby enabling the natural loop inductance to be resonated with a fixed capacitance at the required freqency by changing the overall transformer ratio.

Various arrangements according to the invention will now be described in more detail, by way of example only, with reference to the accompanying drawings, in which:—

Figure 1 is a circuit diagram of one embodiment of the invention,

Figure 2 is a block diagram of four-channel vehicle detection system incorporating circuits according to Fig. 1, and

Figures 3 to 5 are circuit diagrams of further embodiments of the invention.

Referring firstly to Fig. 1, there is shown an oscillator 11 that is coupled to an inductive loop 12 which may be buried in a roadway so as to be influenced by the arrival and departure of vehicles in and from the vicinity of the loop. The oscillator comprises a transistor TR_1 with its collector connected to a low voltage or negative supply rail 13 through a resistor R_5 and a parallel tuned LC resonant circuit comprising an inductor T_1 and a fixed capacitor C_5. The emitter of transistor TR_1 is connected to a positive + 18V supply rail 14 through a resistor R_4 and inductance T_2 and a resistor R_3, and its base is connected to the junction point of resistors R_1, R_2 that form a potential divider between the rails 14, 13. An emitter-base circuit includes the resistor R_4, the inductance T_2 and a capacitor C_1, the whole configuration constituting a conventional emitter-coupled oscillator with feedback from the winding of inductor T_1 to the winding of inductor T_2.

The remaining circuitry provides variable tuning inductance. Two transistors TR_2 and TR_3 are connected to form a current amplifier circuit 15. The transistor TR_3 has its base connected to the junction point of two resistors R_9, R_{10} connected in series between the rails 14 and 13, its collector connected to the rail 13, and its emitter connected to the rail 14 through a resistor R_8. The transistor TR_2 has its base coupled to the emitter of the transistor TR_3, its collector coupled through a capacitor C_3 to the base of a transistor TR_4, and its emitter connected to the rail 14 through a resistor R_7 and through a series-connected resistor R_6 and capacitor C_2 in parallel with the resistor R_7. The current gain of the current amplifier 15 is essentially determined by the resistors R_6, R_7, and its output impedance by the resistors R_9, R_{10}.

The transistor TR_4 is connected in an emitter follower configuration 17 and had its base connected to the low voltage rail through a resistor R_{12}, its collector connected to + 5V and to its base through a resistor R_{11}, and its emitter connected to the rail 13 through a resistor R_{13} and also to a reference voltage input, pin 6, of a digital-to-analogue converter

16 (ZN428E) which is employed as a variable attenuator. The capacitor C_3 has a reactance approximately 17 times that of the parallel resistance of resistors R_{11} and R_{12}. The emitter follower circuit 17 presents a low source impedance at the reference voltage input of the digital-to-analogue converter 16 to maintain its monotonicity and its optimum d.c. operating point. The a.c voltage transfer characteristic of the ZN428E converter 16 is dependent on the digital number applied to it on eight data lines 18, pins 2, 1, 16, 15, 14, 13, 12 and 11, once the enable input on line 19, pin 4, goes low.

The voltage appearing at pin 5 of the ZN428E converter is coupled by a capacitor C4 to the base of the current amplifier transistor TR_3. The current amplifier 15 includes a 180° phase shift and therefore transforms the capacitive voltage into an inductive tuning current, and the amplified inductive tuning current flows from the collector of the transistor TR_2 into the oscillator circuit 11 by way of a connection from the TR_2 collector to the junction point of the resistor R_5 and the LC circuit T_1, C_5. Therefore, by changing the transfer characteristic of the ZN428E converter 16 in the loop including the capacitor C_3, the emitter follower 17, the converter 16 and the capacitor C_4, the loop oscillator operating frequency can be adjusted, and this enables the operating frequency to be digitally programmed according to the digital number applied to the parallel inputs 18.

The dynamic working range of the current amplifier 15 is made larger than the loop oscillator output so that if a noise spike occurs the loop oscillator "bottoms" but the current amplifier remains in its active range, thus maintaining the tuning inductance and noise immunity.

Fig. 2 is a schematic diagram of a four-channel vehicle detector employing programmable loop oscillators as shown in Fig. 1. Each of the four loop oscillators 20 has its operating frequency programmed by means of a loop frequency determining data bus 21. The enable lines 19 are made active on power up or "reset" and a predetermined digital number is fed into each loop oscillator. The resultant loop frequencies appearing on lines 22 are then mulitplexed into microprocessor-based detector circuitry 23 by a "mux" circuit 24. The detector circuit 23 reads the loop frequency for each channel and compares it with an internal register. If the loop frequency is not the desired one, then the digital number applied to the data bus 21 is changed until the desired loop frequency is obtained. The final numbers are latched into the loop oscillators and during normal vehicle movements each oscillator responds in frequency as a normal free-running oscillator.

If, however, large inductance changes occur due to vehicle movements or environmental changes, such as would ordinarily produce a large change in loop oscillator frequency, the detector circuit 23 reacts by latching a new number into the loop oscillator and thereby adjusts the loop frequency to maintain it, in the worst case, within 1KHz, assuming an operating frequency in the band 62 – 78KHz. This is done to avoid cross-talk with another detector working at a different section of the frequency band, and also to maintain the detector within the frequency band.

In detecting the presence or absence of vehicles, the detection routine within the detector circuit 23 can either look at change in loop frequency or change in the number of loop cycles in a given period, for the purpose of producing output signals at the four output circuits 25 corresponding to the four loop oscillators 20. The routine will include a normal environmental tracking facility. However, the exact manner of vehicle presence detection forms no part of this invention and need not be further described here.

Each loop oscillator operating frequency is determined to within approximately 1 KHz by a loop frequency program circuit 26, which may simply consist of a number of manual switches so that the digital number to be latched into each oscillator circuit 20 can be preset. The loop oscillator enable lines 19 are also used to strobe the loop frequency program data into the microprocessor detector circuit 23, so that it responds quickly to change in state of the manual programming switches.

Fig. 1 gives one arrangement of digitally programmable loop oscillator, but there are a variety of ways of achieving the same result and Figs. 3 to 5 show further possible circuits.

Referring to Fig. 3, the emitter coupled oscillator circuit 27 is generally the same except that the LC resonant circuit has been modified with the inductance T_1 divided into two sections. The digital-to-analogue converter 28 performs essentially the same function as before and its output is coupled by a capacitor C_6 to the positive input of a non-inverting amplifier LC_1 which is also connected to the junction point between the two resistors R_9, R_{10} in series between the supply rails 14, 13. A series-connected capacitor C_4 and resistor R_8 provide connection from the negative input of the amplifier LC_1 to the rail 13, and a resistor R_7 is connected between the amplifier output and its negative input. The amplifier output at Y is coupled by an inductor T_3 to point X connected to the junction point of the two sections of the inductance T_1 on the collector of the oscillator transistor TR_1. Two resistors R_5, R_6 forming a potential divider are connected between point X and the rail 13 and the voltage at the junction point of these two resistors is coupled back to the voltage reference input of the converter 28 by the

capacitor C_3.

The input to the variable inductance circuitry is tapped down to make its effective dynamic range larger than the oscillator. The output of the potential divider R_5, R_6 is coupled into the voltage reference input of the D/A converter 28 which is again used as a variable attenuator. The output of the D/A converter is amplified by the non-inverting amplifier, the gain of which is made such that when the D/A converter is at minimum attenuation the a.c. voltage at X is slightly larger than at Y. The inductive tuning current flowing through the inductor T_3 is then very small. When the D/A converter is adjusted by the digital number input to have maximum attenuation, the voltage at point Y is very much smaller than that a X and therefore a large inductive current flows to the output terminal of amplifier LC_1 which has a very low output impedance. The oscillator at this time sees its maximum tuning inductance.

This circuit has an advantage over that of Fig. 1, in that the amplifier formed by LC_1 is operating in a class B mode and therefore its maximum current consumption will be less when operating at minimum loop inductance. The current consumption will depend upon loop inductance and therefore, with a typical loop inductance of 115μH and maximum tuning range of 30μH to 500μH, the typical power consumption could be between one quarter and one eight of that of the Fig. 1 circuit, which operates in a Class A mode.

The circuit of Fig. 4 again uses the emitter coupled oscillator configuration 27 but now the variable tuning is accomplished by means of a variable reactance loop transformer. In this case, the D/A converter 29 is used in the mode in which it provides an output voltage proportional to its digital data input. The two transistors TR_2 and TR_3 are one NPN and the other PNP. The transistor TR_3 has both a collector resistor R_5 and an emitter resistor R_6, and its collector is also connected to the base of transistor TR_2 which has its emitter connected to the rail 14 via resistor R_4 and its collector connected to the junction point of the collector of the oscillator transistor TR_1 and the loop transformer T_1.

The base of the transistor TR_3 is connected to the junction point of resistors R_7 and R_8, resistor R_7 being connected to the supply rail 14 while the output voltage of the converter 29 is applied to the transistor base via the resistor R_8. The output voltage of the converter is thereby effective to vary the d.c. current in transistor TR_2 which consequently alters the phantom inductance of the transformer, and variable tuning is thus accomplished. The collector output impedance of transistor TR_2 is high and, since it is a current amplifier, the d.c. bias current is unaffected by the RF voltage across it. The working Q of the oscillator is thus maintained high.

In Fig. 5, the basic oscillator is again an emitter coupled oscillator with a parallel tuned LC resonant circuit C_5, T_1. However, the inductance of the road loop 12 is transformed to the tank circuit of the oscillator on the collector of the transistor TR_1 by two transformer windings TA_2, TA_1 connected in tandem, the transformer winding TA_1 providing a portion of the inductance T_1 of the oscillator tank circuit. Both transformer windings are multi-tapped and the switching of the taps, to cause the oscillator to run at a programmed frequency, is carried out by analog switches. The switches are effectively single pole nine-way switch banks SW_1, SW_2.

The switch positions are determined by 4 bit binary parallel digital inputs, from 4 bit latches 30, 31 receiving the input from the 8 bit microprocessor bus at 18. These latches receive a common latch signal at 32. Each bit signal is then converted into a 1 of 9 signal so that only one switch of the nine is operative at one time. The conversion is performed by two 4 line to 16 line data converters 33, 34, only nine of the sixteen outputs being used in each case. Each 4 bit signal is referenced to logic 0 so that the micro-computer driving the switch can have the same OV as the oscillator. The analog switch circuitry has + 10V and − 10V supplies since the collector of transistor TR_1 ill swing ± 8 volts about the OV rail.

The most significant 4 bits of the 8 bit microprocessor bus drive the switch for transformer TA_1 and the remaining 4 bits drive the switch for transformer TA_2. The transformer winding TA_1 has coarse tappings with the voltage ratio varying from 1:1 to 3.5:1 approx. The transformer winding TA_2 has fine tappings, the voltage ratio varying from 1:1 to 1:0.85.

The loop amplitude of the circuit shown will vary by 4:1 approximately depending on the loop inductance, being lowest at lowest inductance. A simple amplitude control circuit can be added, if desired, to maintain a constant loop amplitude. The oscillator is designed to maintain the loop frequency within ± 500 Hz at 70 KHz.

The circuit has the advantageous of simplicity, good monotonic performance and good waveform, the latter because the oscillator is fixed capacity tuned and therefore the dynamic resistance of the tuned circuit is approximately constant with different loop inductances.

CLAIMS

1. Inductive loop detector circuitry for sensing vehicles, including a loop oscillator having an LC resonant circuit in which the loop provides part of the inductance, and wherein the overall inductance is variable to vary the tuning of the oscillator operating frequency by means of a tuning control circuit

responsive to application of a variable digital number as control input.

2. Circuitry according to Claim 1, wherein the tuning control circuit comprises a controllable network of which the output voltage or voltage transfer characteristic is variable in accordance with the applied digital number, said variable output voltage or voltage transfer characteristic being arranged to vary the tuning inductance of the oscillator.

3. Circuitry according to Claim 2, wherein the controllable network is a digital-to-analogue converter and the digital number is applied thereto as an 8-bit parallel digital input from a microprocessor.

4. Circuitry according to Claim 2 or Claim 3, wherein the controllable network is connected as a variable attenuator in a feedback loop of a current amplifier delivering an inductance current output that is coupled to the oscillator tank circuit.

5. Circuitry according to Claim 2 or Claim 3, wherein the output of the controllable network is employed to control the phantom inductance of a variable reactance transformer in the tank circuit of the oscillator.

6. Circuitry according to Claim 1, wherein the inductive loop is coupled to the oscillator tank circuit by transformer windings the transformer ratio of which varies in response to the applied digital number.

7. Circuitry according to Claim 6, comprising at least one multi-tap transformer winding and switch means arranged to change the tap connections to vary the transformer ratio in response to the applied digital number.

8. A multichannel inductive loop vehicle sensing system, wherein each channel includes a digital-number-responsive variable-operating-frequency oscillator according to Claim 1, and programming means are provided for applying a different digital number to each oscillator so that the channels operate at distinctly different frequencies without crosstalk.

9. An inductive loop vehicle sensing system according to Claim 1 including a programmable loop oscillator substantially as described with reference to any of Figs. 1 and 3 to 5 of the accompanying drawings.

10. A multi-channel inductive loop vehicle sensing system, wherein each channel includes a programmable loop oscillator according to Claim 1, and substantially as described with reference to Fig. 2 of the accompanying drawings.

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